Riverbank Filtration Effectiveness in an Arid Environment

Project Scope

Riverbank filtration is a relatively simple and low-cost means for removing particulates and microorganisms from surface water by placing pumping wells in alluvial sediments of the river or stream banks. The sediments act as a filter that traps and attenuates microorganisms and some organic pollutants. During riverbank filtration, waters with different chemical and microbial compositions mix, resulting in complex interactions between soil, microorganisms, pollutants, and dissolved solids. For example, organic solids can be concentrated in the alluvial sediments, and subsequent microbial reduction can create an anaerobic zone where heavy metals are mobilized. Beyond the anaerobic zone, however, there may be an aerobic zone where trace elements and heavy metals are immobilized and where organic pollutants can be biodegraded to harmless compounds.

In humid climates, riverbank filtration has been shown to effectively remove dissolved organic constituents and heavy metals. However, few data are available regarding the performance of this technology in arid climates, including the Rio Grande River valley that separates the United States and Mexico. In arid climates, riverbank filtration technology is more difficult to apply because water level and salinity can vary seasonally, sediments often consist of heterogeneous sand-dominated river deposits, and because of possible long-term salt or arsenic accumulation in the sediments. Despite these difficulties, shallow wells in the Rio Grande alluvium are used as drinking water sources, without further treatment, for residents of many small communities located on both sides of the United States-Mexico border. Increased knowledge about the effectiveness of riverbank filtration can help prevent outbreaks of waterborne disease and provide affordable water supplies for residents of both countries. In addition, the large cities along the Rio Grande are rapidly drawing down their groundwater aquifers, and future plans call for increased use river water. Riverbank filtration may thus provide a cost-effective water pretreatment method for these cities.

The overall objective of this research was to determine whether riverbank filtration in an arid environment is effective at removing particulates and microbial pathogens. A series of field experiments were conducted over the course of the research project at the Rio Bosque Park, located in southwest Texas within the corporate limits of the City of El Paso. The experiments involved installing a model

Grant Title and Principal Investigators

Riverbank Effectiveness in an Arid Environment (EPA Grant #R829009)

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Key Findings and Implications

Analytical Accomplishments:

- Riverbank filtration appears to be an effective tool to prevent the migration of protozoan (oo)cysts; however, it does not appear to totally remove or diminish the migration of waterborne bacteria.
- Bromide and differentially sized microspheres were successfully used to assess protozoa (oo)cyst migration under riverbank filtration conditions.

Implications of Research and Impacts of Results:

- Demonstrated that bacterial indicators can be used to study the transport of microbial pathogens during riverbank filtration conditions. However, a suite of indicator organisms is recommended.
- Provides information to improve water treatment is arid regions where water is scarce.

Publications include 1 book chapter and 4 conference/symposium presentations.

Project Period: September 2001 to December 2004

Relevance to ORD's *Drinking Water Research Multi-Year Plan* (2003 Edition)

This project contributes to two of three Long-Term Goals for drinking water research: (1) By 2010, develop scientifically sound data and approaches to assess and manage risks to human health posed by exposure to regulated waterborne pathogens and chemicals, including those addressed by the Arsenic, M/DBP, and Six-Year Review Rules; and (3) By 2009, provide data, tools and technologies to support management decisions by the Office of Water, state, local authorities and utilities to protect source water and the quality of water in the distribution system.

The preliminary and future results from this research project will help lead to improved understanding of the effectiveness of riverbank filtration in arid environments. It can help prevent outbreaks of waterborne disease and provide affordable water supplies for residents of the United States and Mexico that are increasingly relying on Rio Grande River water for domestic purposes. It can also inform research and future risk management decision-making on the use of riverbank filtration as a water pretreatment method in arid regions. More specifically, although preliminary findings indicate that riverbank filtration appears to be an effective tool to prevent the migration of protozoan (oo)cysts, it does not appear to totally remove or diminish the migration of waterborne bacteria.

pumping well, along with several monitoring wells, near an artificial channel of the Rio Grande River. This research was intended to address the following questions:

1. Do stratigraphic (i.e., geologic layering) heterogeneities reduce the effectiveness of bank filtration?
2. Does variation in salinity and water depth change the effectiveness of riverbank filtration?
3. Does pumping rate change the effectiveness of riverbank filtration?

The wells were used to characterize the distribution and transport of microorganisms (pathogens and microbial pathogen indicators) and the dispersion patterns of water flow between the river and the pumping well. Site stratigraphy was characterized by detailed analysis of sediment cores collected from the wells. Water samples were collected and analyzed for water chemistry at least twice each month during each of the three years of the project, while the experimental well was pumped at different rates. Additional samples were collected during seasonal channel flooding (approximately November to February). Water samples were analyzed monthly for a several microbial pathogens and a variety of microbial pathogen indicators. A three-dimensional model of water flow between the river and the well was under development at the end of the grant period to help measure the effectiveness of riverbank filtration.

Although data collection for this research project was complete at the time this summary report was prepared, much of the analysis was still ongoing or planned. Thus, many of the results summarized below are preliminary.

Project Results and Implications

<u>Characterization of Soil/Sediment and Geochemistry</u>: Analysis and characterization of the soil/sediment cores revealed a total of six types across the study site, including a fine-grained sediment interval that might effectively restrict the migration of coarse particles such as bacteria and larger microorganisms. Geochemical water quality parameters remained relatively constant during course of the study, with no significant changes observed during the weeks-long sampling periods. The primary solutes were sodium chloride and calcium sulfate; the typical total dissolved solids (TDS) concentration was slightly above 1,000 mg/L (above the National Secondary Drinking Water Regulation for TDS of 500 mg/L. Although nutrient concentrations were found to be relatively low in natural groundwater, pumping of the

experimental well resulting in increased levels of Kjeldahl nitrogen (i.e., sum of organic and ammonia nitrogen) and phosphorus, presumably drawn in from the river channel.

<u>Characterization of Aquifer and Flow Between Riverbank and Well</u>: Characterization of the aquifer was incomplete but background water samples were taken from the pumping well, selected monitoring wells, and the Rio Grande drainage channel. These samples were analyzed for major cations and anions, several bacterial nutritional parameters (e.g., total phosphorus, Kjeldahl nitrogen), pesticides, and polychlorinated biphenyls (PCBs). Background levels of pathogens and indicator microorganisms were also measured with preliminary results revealing a heterogeneous distribution of bacteria and phages (viruses that infect bacteria and used as an indicator of viral pathogens) and highlighting the importance of the heterogeneities in the sediments. Additional background water samples were collected from the canal to determine whether indicator bacteria and viruses could be used as indicators of microbial pathogen transport without the need for injecting actual waterborne pathogens into the experimental system. Somatic coliphages were detected in the canal which was also positive for *Escherichia coli*, enterococci, and fecal coliforms but negative for *Salmonella* species. None of the background samples were positive for *Cryptosporidium parvum* oocysts or *Giardia lamblia* cysts, suggesting the use of microspheres (as surrogates) was necessary to characterize protozoan pathogen transport.

A total of four pump tests were conducted over the course of the research, one at a “low” pumping rate (40 gallons/minute) and three at a “high” rate of 79 gallons/minute. Preliminary pump test results indicated that riverbank filtration appears to be an effective tool to prevent the migration of protozoan (oo)cysts. However, riverbank filtration does not appear to totally remove or diminish the migration of waterborne bacteria as they migrated at nearly the same rate at low and high pump rates. Specifically, *E. coli* and enterococci were found in diminished numbers in the pumping well as compared to the canal, which suggests that bacterial pathogens could break through natural barriers during riverbank filtration.

<u>Protozoa Tracer Experiments</u>: A 430-hour (18-day) tracer test was conducted in second year of the research project to further study potential pathogen transport. This study included a conservative, rapidly moving tracer (bromide) and microspheres in three different sizes (1 µm, 6 µm, and 10 µm) and colors (yellow-green, red, and blue) to mimic the transport behavior of oocysts and cysts of the enteric protozoa, *G. lamblia* and *C. parvum*, respectively. Preliminary results on microsphere occurrence and breakthrough suggested that (oo)cyst transport for these waterborne protozoa was similar to patterns documented by other researchers. In general, bromide and microspheres were found in low concentrations in experimental wells throughout the experiments and peaks in microsphere abundances were correlated with peaks of bromide concentration. Microspheres appeared up to one hour earlier than the bromide, indicating flow in preferential paths through larger pores. However, the transport differences between individual wells were more profound, with wells showing tracer/microsphere peaks that differed across 36 hours. These results indicate that (1) there are preferred high-permeability flow pathways in the sediment and (2) the bromide tracer and microsphere concentrations were initially diluted because of the effect of being released slowly from the lower conductivity media and then dispersed in higher volumes through the preferential flow pathways. Additional research was planned to model the observed behavior to identify the parameters that control protozoa transport and occurrence in field applications of riverbank filtration.

<u>Summary</u>: These preliminary results suggest that riverbank filtration appears to be an effective tool to prevent the migration of protozoan (oo)cysts, although it does not appear to remove or significantly diminish the migration of waterborne bacteria. However, bacterial indicators can be used to study the transport of microbial pathogens during riverbank filtration conditions. The differences in the behavior of several bacterial and viral indicator organisms, however, suggest that a suite of indicator organisms needs to be used to accurately assess the migration of microorganisms in the subsurface environment during riverbank filtration conditions.

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For More Information

NCER Project Abstract and Reports:

http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/1065/report/0

Peer Reviewed Publications

None.